Carbon Dioxide Emission by Major Fuel Consuming Countries: A Panel Data Analysis

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Abstract

This paper examined the factors that determine the carbon dioxide emission in USA, Japan, China and India during the period 1970 to 2008. The statistical results show that increased CO_2 emission is a factor of increased fuel consumption across countries, and does not happen simply due to the passage of time. The results of the panel, indicate a direct relation with fossil fuel consumption but not as much with the population increase. There is minor variation in the results of fossil fuel consumption variables across countries, in case of coefficients being statistically significant. However, the significance level is very low in case of population variable in some of these countries. The panel data analysis suggests that the carbon dioxide emission is mainly a factor of heavy fossil fuel consumption, and not merely due to increase in population.

Keywords

Carbon dioxide; Fossil Fuel; Petroleum Oil; Coal; Natural Gas; Population; Panel Data Analysis

Introduction

Carbon dioxide (CO_2) cannot be classified as an air pollutant due to its reasonable abundance in the natural atmosphere (0.037%) [2]. The primary source of carbon dioxide emissions is the natural degradation of marshes and forests; increased economic activities due to the growth of population, increase in fossil fuel consumption etc. In the natural 'carbon cycle', atmospheric carbon dioxide is normally removed by two major 'sinks' viz. plants which absorb CO_2 during the process of 'photosynthesis' and second one is oceans. But the problem has arisen because the speed of the CO_2 produced is faster than that of absorption by the sinks. Increasing CO_2 level has an influence on climate through the 'greenhouse effect'; leading to the danger of the earth gradually being heated up. If the earth continues to warm up, all the glaciers will recede and the ice caps in the Antarctic and the Arctic will begin to melt. Consequently, the sea level will rise, causing the shrinking of coastal regions. Since the beginning of the 20th century, the global population and economic activities have steadily increased leading to a rise in fossil fuels consumption and in turn increasing the level of carbon dioxide in the atmosphere. It has been estimated that the global consumption of fossil fuels results in the release of nearly 9×10^9 tonne of carbon dioxide per year. Since 1751, approximately 337 billion tons of carbon have been released to the atmosphere derived from the consumption of fossil fuels and cement production. Half of these emissions has occurred since the mid 1970s. The global fossil-fuel carbon emission estimates in 2007 is 8365 million metric tons of carbon, representing an all-time high and a 1.7% increase from 2006. Globally, liquid and solid fuels contributed to 76.3% of the emissions from fossil-fuel burning and cement production in 2007. Combustion of gas fuels (e.g., natural gas) amounts to 18.5% (1551 million metric tons of carbon) of the total emissions from fossil fuels in 2007; which is a gradual increase in global utilization of natural gas. Emissions from cement production (377 million metric tons of carbon in 2007) have more than doubled since the mid 1970s and currently represent 4.5% of global CO_2 releases from fossil-fuel burning and cement production. Gas flaring, which amounted to roughly 2% of global emissions during the 1970s, now less than 1% of global fossil-fuel releases [3].

Historically, the United States had been the leading emitter of pollutants. Between1960 to2005, the U.S. has emitted 213,608 Mt CO_2, which amounts to 26% of total global emissions; whereas China, the next biggest

polluter, has emitted 88,643 Mt CO_2 over the same time frame which comes out to be 10.7% of global emissions. However, according to the Netherlands Environmental Assessment Agency, China has overtaken the United States as the world's biggest producer of carbon dioxide; which may be due to increased industrial activities and soaring demand for fossil fuel. India is the third largest CO_2 emitter, followed by Russia and Japan. The fossil fuel consumption by Russia, Japan and India are 610, 435 and 404 million tonnes respectively [4]. Researchers have tried to establish existence of a strong causal relationship between fossil fuel consumption and carbon dioxide emission [11, 24]. Throughout history, the expansion of human population has been the major contributor to the increase in fossil fuel consumption [9, 1, 15, 19]. Economic development and a rapidly growing population nowadays are putting strain on the environment, infrastructure and country's natural resources. Increasing global consumption of fossil fuels steadily pushes up the carbon dioxide level in the atmosphere, which may probably bring about drastic changes in the world climate [8]. The changes in climate subsequently affects the health of human being, animal and plant [22]. Therefore, in this study, the causal relationship between carbon dioxide and the two factors fossil fuel and population is analysed. The panel data of four major fuel consuming countries viz. United States, China, Japan and India, for the period from 1970 to 2008 is used for analysis. Russia has not been included due to unavailable data for time series.

Carbon Dioxide Emission and Fossil Fuel Consumption in Different Countries

Fossil fuels are universally recognized as one of the most important ingredients propelling economic growth and human development. Fossil fuels consist of petroleum oil, coal and natural gas. The growth of a nation, encompassing all sectors of economy and all sections of society is contingent on the extent to which whether the country can meet the energy requirement the development needs [23]. Pirog observed that the strongest growth performances were in oil import of United States and China; besides Japan, Russia and other developing nations like India also with good performances [21]. We now present country wise scenario.

USA is the world's third-largest country by size after Russia and Canada; while by population after China and India. In addition, USA is the largest economic entity and one of the countries with the most advanced technology [6]. For any economy, energy, particularly the fossil oil plays an important role in driving growth. Today, United States is the largest consumer of fossil fuel and consumes more energy from fossil fuel than from any other energy source. In 2008, total USA fossil fuel consumption was 44% of world's fossil fuel consumption. USA's net oil imports were approximately 487.2 million tonnes in 2008, making it the largest net oil importer in the world [10]. It has the largest coal reserves with 491 billion short tons occupying 27% of the world's total. The share of coal consumption by US is 17% of the world's total, but after 2009, both production and the consumption of coal have declined significantly. Total natural gas consumption in US is 22% of the world's consumption. Natural gas is consumed mainly in the industrial (38%), electric power (24%), residential (22%), and commercial (13%) sectors. United States , the world's second largest fossil fuel-related CO_2 emission country behind China, has emitted almost 90 billion metric tons of carbon since 1800 from fossil-fuel consumption and cement production. Its fossil-fuel emissions have doubled since the 1950s but the share of global emissions has declined from 44% to 20% over the same interval because of higher growth rates in other countries.

In 2007, 41% of U.S. fossil-fuel emissions came from the consumption of petroleum products. The United States was completely reliant on coal until after the Industrial Revolution and now the coal usage amounts to 37% of its fossil-fuel CO_2 emissions. Table I reveals that after 39 years, the CO_2 emission reached the level of 6371.39 million tonnes growing at an average annual rate of 0.9%; whereas the growth in fossil fuel consumption during the same period had been about 0.8%; and the population had an annual growth rate of 1%. A fall in CO_2 emission can be seen between 1980 and 1985, and again in 2005 and 2008, which may be due to the corresponding fall in fossil fuel consumption. Due to economic downturn followed by global recession in the US; GDP got contracted, causing the severest and longest downturn since the Great Depression. Long-term problems included inadequate investment in economic infrastructure, sizable trade and budget deficits, and stagnation of family income in the lower economic groups [6], which caused a reduction in demand of oil and consequently falling CO_2 emissions [14].

Table I. CO_2 Emission Fuel Consumption and Population in USA

Years	CO_2 (Million Tonne)[a]	Fossil Fuel (Million Tonne)[a]	Population (Million)[b]
1970	4652.07	1552.88	209.46
	(1.67)	(1.57)	(0.90)
1975	4802.21	1587.67	219.11
	(2.98)	(2.74)	(0.93)
1980	5181.52	1692.68	229.47
	-(0.72)	-(1.06)	(0.93)
1985	5009.19	1606.74	240.61
	(2.43)	(2.46)	(1.15)
1990	5480.49	1758.95	254.87
	(1.28)	(1.40)	(1.20)
1995	5833.13	1885.26	270.65
	(1.75)	(1.63)	(1.26)
2000	6426.78	2066.99	287.84
	(0.37)	(0.32)	(1.02)
2005	6539.56	2094.67	302.74
	-(0.85)	-(0.69)	(0.97)
2008	6371.39	2050.23	311.67

[a] BP Statistical Review of World Energy, 2009

[b] UN Population Division, World Population Prospects, 2008

Figure in the parenthesis are average yearly growth rate

China, the world's most populous country, has a rapidly developing economy. For the past several years, China's gross domestic product (GDP) has had double digit growth. Nowadays it is the second-largest economy in the world after the US. However, in per capita terms China has still a long way to go. Thirty years back, China was a closed economy when all the assets were publicly held. Reforms started in the late 1970s with the phasing out of collectivized agriculture, and expansion on the gradual liberalization of prices, fiscal decentralization, increased autonomy for state enterprises, the foundation of a diversified banking system, the development of stock markets, the rapid growth of the non-state sector, and the opening up of market to foreign trade and investment. The restructuring of the economy and resulting efficiency gains contributed to more than twenty fold increase in GDP since 1970. The recent global financial crisis caused China's GDP to slow down from highs of 13% in 2007, to 6.1% in the first quarter of 2009, the lowest quarterly rate in 10 years [6].

At present, China confronts numerous economic developmental challenges. The rapid pace of growth is not without problems. Mass scale industrialization has led to the deterioration in the environment and air quality. Industrialization and massive construction activities have brought about the reduction in greenery and vegetation, causing soil erosion. The water table has also steadily fallen. In 2006, China announced that by 2010 it would decrease energy intensity by 20%, consequently reducing the carbon intensity by 40% in comparison to 2005 levels. But despite the economic slowdown, China's demand for energy remains high and as a consequence from being the net exporter in the 1990s, it has become a net importer of oil. Oil amounts to about 20% of the country's total energy consumption, whereas coal is 70% and natural gas is 3% only [10]. China consumed an estimated 375.71 million tonnes of oil in 2008, making it the second-largest oil consumer in the world behind the United States; whereas, the oil production was an estimated 189.7 million tonnes [10]. China , as the largest consumer and producer of coal in the world, holds an estimated 114.5 billion short tons of recoverable coal reserves, the third-largest in the world behind the United States and Russia and about 13% of the world's total reserves. In 2008, China consumed an estimated 3 billion short tons of coal, representing nearly 40% of the world's total consumption. Historically, natural gas has not been a major energy source in China, but its share in the country's consumption mix is slowly increasing. Coal production and use in China has increased ten-fold since the 1960s and as a result, Chinese fossil-fuel CO_2 emissions have grown to a remarkable 92% since 2000 alone. China has become the world's largest emitter of CO_2 due to fossil-fuel use and cement production. From 1970 to 1997, China's fossil-fuel CO_2 emissions rose at an annual rate of 5.4%. Growth has occurred largely in the use of coal, not surprisingly due to obvious reason, which contributed to 98.7% of the emissions in 1950 and 72% in 2007. Liquid fuels now contribute to 15.5% of emissions and have grown appreciably over the past decade. Per capita emissions increased considerably over this period and the year 2006 was the first time when China's per capita emission rate (1.27 metric tons of carbon) exceeded the global average (1.25 metric tons of carbon). From Table II it can be observed that in the last 39 years, both CO_2 emission and fossil fuel consumption have increased by over eight times which is an average annual increase of 4.8%; whereas the increase in population has only been about 1.64 times amounting to a meager 1.3%. However, after 2000, CO_2 emission and fossil fuel consumption are significantly high, which may be due to high growth rate of GDP.

Table II. CO_2 Emission Fuel Consumption and Population in China

Years	CO_2 (Million Tonne)[a]	Fossil Fuel (Million Tonne)[a]	Population (Million)[b]
1970	871.01	227.27	801.27
	(7.36)	(7.96)	(2.32)
1975	1222.45	327.11	895.02
	(7.10)	(7.18)	(1.51)
1980	1501.25	403.30	963.12
	(4.43)	(4.14)	(1.40)
1985	1930.44	512.18	1033.91
	(6.06)	(6.04)	(1.68)
1990	2478.09	656.45	1121.69
	(5.42)	(5.46)	(1.22)
1995	3281.27	870.71	1189.61
	(0.14)	(0.49)	(0.93)
2000	3383.61	913.13	1244.68
	(10.22)	(10.20)	(0.72)
2005	5466.27	1470.36	1289.48
	(8.06)	(8.05)	(0.64)
2008	6896.54	1854.63	1314.36

[a] BP Statistical Review of World Energy, 2009
[b] UN Population Division, World Population Prospects, 2008
Figure in the parenthesis are average yearly growth rate

Japan is the third largest economic entity in the world, just behind the United States and China. In the years following World War II, government-industry cooperation, a strong work ethics, technological advancement, a comparatively small defense allocation (1% of GDP), etc. helped Japan to develop into technology oriented economy. Soon after World War II, the Japanese started rebuilding their economy andafter three decades its growth was at the rate of around 10%. Thereafter, the growth rate kept declining to reach a level of 1.7% per annum in the 1990s. Japanese economy rather started contracting in 2008, with the interest rates getting to a near zero percent in the year 2009. A sharp downturn in business investment and global demand for Japan's exports in late 2008 pushed Japan further into recession. Due to lack of any oil resources of its own, Japan started making overseas investments in oil and gas projects. Over the years, its mass production capability has multiplied its energy consumption, however, unlike most other countries, its oil consumption has not gone up at the same proportion due to its conscious effort to get rid of dependence on oil for energy needs to alternate energy sources and efficient manufacturing technologies. The share of oil consumed as a percentage of the primary energy mix both in the manufacturing and transport sector over the years has gone down substantially from roughly 80% in 1970s to around 50% today. Preliminary data indicates that Japan consumed nearly 221.8 million tonnes of oil in 2008, making it the third largest petroleum consumer in the world behind the United States and China (Table III). Due to the gap between domestic consumption and production, Japan remains the second-largest net importer of oil after the United States [10]. Despite limited natural gas resources, Japan is a large natural gas consumer i.e. 20% of its total energy consumption and therefore relies on imports for virtually all of its natural gas needs.

Table III. CO_2 Emission Fuel Consumption and Population in Japan

Years	CO_2 (Million Tonne)[a]	Fossil Fuel (Million Tonne)[a]	Populatio n (Million)
1970	858.97	262.42	104.45
	(5.01)	(5.43)	(1.37)
1975	984.76	305.96	111.62
	(1.85)	(2.21)	(0.94)
1980	1010.98	316.94	116.79
	(0.44)	(0.38)	(0.73)
1985	1008.40	314.53	120.91
	(2.48)	(2.62)	(0.38)
1990	1165.30	366.94	123.19
	(2.18)	(2.25)	(0.38)
1995	1287.82	405.91	125.44
	(0.28)	(0.35)	(0.21)
2000	1331.01	419.39	126.71
	(0.99)	(0.72)	(0.13)
2005	1398.07	436.10	127.45
	-(0.17)	-(0.09)	-(0.04)
2008	1390.63	434.83	127.29

[a] BP Statistical Review of World Energy, 2009
[b] UN Population Division, World Population Prospects, 2008
Figure in the parenthesis are average five years growth rate

Today, Japan is the largest importer of liquefied natural gas (LNG) in the world and occupies about 40% of global LNG imports. Coal is still a significant share i.e. 20% of total energy consumption. With postwar growth at 9.8% per year from 1950 to 1973, total emissions were virtually constant from 1974 through 1987,during which emissions increased by 31.8% due to rise in the consumption of liquid petroleum products, coal and natural gas. Japan's per capita fossil-fuel and CO_2 emission rate for 2007 stood at 2.71 metric tons of carbon. Table III reveals that over the past four decades, Japan's population growth has been a mere 0.4%. Average annual CO_2 emission and fossil fuel consumption has been increasing by 1.2 %. There has been about sixty percent increase both in CO_2 emission and fossil fuel consumption in 39 years. Interestingly, after 2005, a negative growth rate in CO_2 emission, fossil fuel consumption and population, can be observed. This may be due to the decline in economic growth after 1990sand declining dependence on oil for energy needs to alternate energy sources; as well as efficient manufacturing technologies; increasing awareness or some combination of any of these factors.

Among the large global economies, India is one of the fastest emerging global economies, averaging more than 7% since 1997. This accelerated pace of growth began with the opening up of the economy in the early 1990s. The global industrial slowdown in early 2008, due to the global financial crisis, led to a marginal deceleration in annual GDP growth rate to 6.1% in 2009 [6]. With high rates of economic growth and over 15% of the world's population, India has become a significant consumer of energy resources [6]. In 2008, India was the fourth largest oil consumer in the world. It lacks sufficient domestic energy resources and therefore, forced to import much of its growing energy requirements especially the petroleum oil. India is currently dependent on imports for 68% of its oil consumption [10]. Coal contributes to more than half of India's total energy consumption followed by oil, and the natural gas to 31% and 8% respectively. Though India is the third largest producer of coal,it is of poor quality and low calorific value. From 1950 to 2007, India experienced dramatic growth in fossil-fuel CO_2 emissions averaging 5.7% per year and has become the world's third largest fossil-fuel CO_2-emitting country. Indian total emissions from fossil-fuel consumption and cement production have more than doubled since 1992. Fossil-fuel emissions in India continue to result largely from coal burning. Coal contributed to 87% of the emissions in 1950 and 71% in 2007; whereas during the same time, the oil fraction increased from 11% to 20%. India's per capita emission rate for 2007 of 0.39 metric tons of carbon is well below the global average (1.25 metric tons). It can be seen that both fossil fuel consumption and carbon dioxide emission have grown by about 7 times, whereas the population has almost double that of 1970 level (Table IV). The average annual growth rate in CO_2 emission and that of fossil fuel consumption is about 5%. During the period of 2003 to 2008, the average annual growth of GDP has been on a high at 8.5%; whereas, the growth rate of fossil fuel consumption and carbon dioxide emission has decreased.

Among the four countries, USA has consumed the highest fossil fuel, followed by China, Japan, and India in that order. China is still the most populous country followed by India. In recent times China has overtaken USA to become the largest CO_2 emitting country. Similarly, since 2008 India has overtaken Japan to become the third largest CO_2 emitting country. The rate of increase in fossil fuel consumption has been the highest in India and China; whereas Japan's population growth has been the least among the four countries.

Table IV. CO_2 Emission Fuel Consumption and Population in India

Years	CO_2 (Million Tonne)[a]	Fossil Fuel (Million Tonne)[a]	Population (Million)[b]
1970	210.20	57.66	552.96
	(4.42)	(4.40)	(2.22)
1975	264.89	72.48	617.43
	(4.32)	(4.62)	(2.33)
1980	324.50	89.40	692.64
	(5.80)	(6.01)	(2.28)
1985	430.23	119.92	774.77
	(8.17)	(8.28)	(2.17)
1990	581.91	164.24	862.16
	(4.77)	(4.80)	(2.05)
1995	766.20	217.09	953.15
	(4.11)	(4.49)	(1.83)
2000	953.79	274.11	1042.59
	(4.13)	(4.07)	(1.65)
2005	1173.99	336.11	1130.62
	(2.98)	(2.74)	(0.93)
2008	1419.38	403.60	1181.41

[a] BP Statistical Review of World Energy, 2009

[b] UN Population Division, World Population Prospects, 2008

Figure in the parenthesis are average yearly growth rate

Methodology

In panel econometrics, fixed effect models rely on the hypothesis that elasticity is constant over the years and across the countries. Panel data are better suited to study the dynamics of changes and detect and measure effects that simply cannot be observed across the countries or over the years alone [13]. Some authors said that fossil fuel elasticity is significant for carbon dioxide emission [12, 17, 18], whereas others have found that the income elasticity is more significant in carbon dioxide emission [1, 14]. Population growth is also regarded as a determinant for increase in carbon dioxide emission [20, 24]. However, in this paper, the change in carbon dioxide emission (CO_2) has been analyzed with respect to fossil fuel consumption (Fuel) and the population growth (Pop). Therefore, the data of four major oil consuming countries have been obtained viz., United States, China, Japan and India. Data of each country on the preceding three variables are available for the period 1970 to 2008. Apriori, CO_2 is expected to be positively related to fuel and population. Since all the four countries have the same number of yearly observations, this panel (data) is called a balanced panel. The simplest way to deal with such data would be to estimate a pooled regression with fixed effects models dependent on the assumptions of the intercept, the slope coefficients and the error term. Here the

slope captures the rate of change in CO_2 due to the corresponding change in Fuel and Pop. The intercept reflects the impact of all extraneous factors, such as the role of respective country's political situation, inflation, consumption pattern, rate of modernization, culture, taste, and preferences, etc.

Output Analysis

Intercept and Slope Constant Across Time and Countries

In this scenario, it is assumed that CO_2, fuel and population across the four countries have the same characteristics; and hence, all the 156 observations are treated as if they belong to same single time series, and the analysis is performed accordingly.

$$\ln CO_2 = 0.97 + 0.97 \ln Fuel + 0.07 \ln Pop \quad (1)$$
$$(37.95) \quad (374.15) \quad (24.87)$$
$$R^2 = 0.98; \quad \text{Durbin-Watson} = 0.7$$

All the coefficients of equation (1) are individually statistically significant. As per expectation, the slope coefficients of both fuel and population have positive signs, thus indicating that the rise in fuel consumption and population causes a corresponding increase in CO_2 emissions. A relatively high R^2 value indicates that the changes in CO_2 emission are almost entirely captured by the two economic variables defined in the model. Low Durbin-Watson statistic suggests that perhaps there is autocorrelation in the data. Further, a higher positive coefficient of fuel indicates that the elasticity of carbon dioxide emission with respect to fossil fuel consumption is significantly higher than that of population growth. The estimated model assumes that the intercept values of USA, China, Japan and India are the same. It also assumes that the slope coefficients of fossil fuel consumption and population growth respectively are also the same for the four countries. Obviously, these are highly restricted assumptions. Therefore, the pooled regression equation (1) may distort the true picture of the relationship between CO_2 emission with fossil fuel consumption and population growth of the four countries.

Slope Coefficients are Constant but the Intercept Varies across Countries

Intercept captures the emission of CO_2 due to factors other than the ones forming part of this study. Here we try to use separate intercept for each of the four countries and study the changes in carbon dioxide emission pattern, because these extraneous factors like consumption patterns, rate of modernization, culture, tastes and preferences, state politics etc. may vary across countries. The model with country wise fixed effect becomes as follows:

$$\ln(CO_2)_{it} = 1.11 + 0.09D_{2i} + 0.02D_{3i} + 0.01D_{4i} + 0.97\ln Fuel_{2it} + 0.05POP_{3it} \quad (2)$$
$$(23.63) \quad (3.29) \quad (3.57) \quad (0.18) \quad (178.93) \quad (3.33)$$
$$R^2 = 0.99 \quad \text{Durbin-Watson} = 0.9$$

Intercept: USA = 1.11, China = 1.20, Japan = 1.13, India = 1.12

Where i = 1, 2, 3, 4 stands for four countries and t = 1, 2, ……39 stands for years. From the *t* statistics shown in brackets in equation (2), it can be observed that except India (D_{4i}) all other estimated coefficients are individually highly significant. The R^2 value and the Durbin-Watson statistic have improved, which may be indicating the effect of increase in CO_2 emissions may be due to increased consumption of fuel in all the countries, except India. The intercept values of the four countries are statistically different, which may be due to unique features of each country, such as income, population, technology etc. Therefore, it is reasonable to conclude that individual country's effects on the carbon dioxide emission cannot depend on the same set of extraneous variables for all the countries. However, the intercept of China is significantly higher than that of the other three countries, which may be due to the construction activity [20].

Slope Coefficients are Constant but the Intercept Varies Across Time

Considering the effect of extraneous variables to be constant for all countries, an attempt is made to identify parameters for the explanatory variable over 39 years. The observed yearly effect for each individual country, on the CO_2 emission equation (1) shifts over years,is given below.

$$\ln(CO_2)_{it} = 0.95 + \ldots\ldots\ldots\ldots + 0.97\ln(Fuel)_{2it} + 0.07\ln(Pop)_{3it} \quad (3)$$
$$(25.13) \quad (305.15) \quad (21.65)$$
$$R^2 = 0.98 \quad \text{Durbin-Watson} = 1.08$$

Almost all intercepts i.e. individual yearly dummy variables i.e. from D_{1970} to D_{2008} are not significant and the coefficients are nearly the same. The R^2 value of the yearly effect is found to be 0.98 in equation (3), which is 0.01 less than that obtained in equation (2). Thus from (2) and (3), it is observed that the individual country's effects are statistically significant, rather than the individual year effects. This might suggest that perhaps the CO_2 emission function has not changed much over time or it may be a chance of misspecification of the model. Hence, it is better to consider both the individual country and yearly effects together.

Slope Coefficients are Constant but the Intercept Varies over Time and Countries

Here the slope coefficients for fuel and population across the country and the year are kept constant; whereas intercepts are varied over 39 years. The observed individual country and year effect on CO_2 emission equation (1) shifts over years as well as country are given below.

$$\ln(CO_2)_{it} = \underset{(15.02)}{1.37} + \underset{(4.37)}{0.16D_{2i}} - \underset{(-1.31)}{0.12\, D_{3i}} + \underset{(1.88)}{0.06D_{4i}} + \ldots + \underset{(166.15)}{0.97\ln(Fuel)_{2it}} + \underset{(0.15)}{0.01\ln(Pop)_{3it}} + u_{it} \quad (4)$$

$R^2 = 0.99$ Durbin-Watson = 1.04

Intercept: USA = 1.37, China = 1.52, Japan = 1.35, India = 1.34

Similar to the results in equation (4), the coefficients of time periods are not individually statistically significant. The intercept of country effect produced low level of significance in case of Japan. Similarly, the significance level of the coefficients of Pop is very low. The overall analysis reveals that the increased CO_2 does not happen with the passage of time, but is related to the increased fuel consumption in all the countries being analyzed in our study. In other words, the CO_2 emission function for the four countries is the same except for their intercepts. In all the cases that have been considered, the fuel consumption variable has a strong impact on CO_2 emission.

Intercept and Slope Vary Across Countries

Finally, the model is developed to study the individual country effect on CO2 emission by varying both the intercept and explanatory variables, across countries and over the year. Then, the CO2 emission in equation (1) provides the output as given below.

$$\ln(CO_2)_{it} = \underset{(15.01)}{0.87} + \underset{(3.74)}{0.23D_{3i}} + \underset{(463.86)}{0.96\ln(Fuel)_{2it}} + \underset{(8.52)}{0.09\ln(Pop)_{3it}} + \underset{(1.42)}{0.01D_{2i}\ln(Fuel)_{2it}} - \underset{(-2.13)}{0.03D_{3i}\ln(Fuel)_{2it}} - \underset{(-5.83)}{0.04D_{4i}\ln(Fuel)_{2it}} + \underset{(4.61)}{0.02D_{4i}\ln(Pop)_{3it}} \quad (5)$$

$R^2 = 0.99$ Durbin-Watson = 1.08

Excluded Variables: D_{2i}, D_{4i}, $D_{2i}\ln(Pop)_{3it}$ and $D_{3i}\ln(Pop)_{3it}$

Intercept: USA = 0.87, Japan = 0.87

Slope of Fuel: USA = 0.97, China = 0.93, Japan = 0.93, India = 0.93

Slope of Pop: USA = 0.09, India = 0.11

The intercept of China and India, and slope of population variable of China and Japan are excluded from the model, and therefore these are not computed and presented here. The differential intercepts of USA and Japan are statistically significant and are almost same. On the other hand, the slope of fuel consumption is same for all countries, except USA. However, population slope differs for different countries. These results reveal that carbon dioxide emission is highly influenced by fuel consumption for almost the four countries. Above all, it shows that the CO_2 functions of the four countries are different.

Conclusions

In this paper the carbon dioxide emission with respect to the growth of fossil fuel consumption and population of four major fuel consuming countries is studied by using panel data analysis. The differential effects of the periods obtained from the panel data analysis are included in the analysis. The results indicate that growth in carbon dioxide emission moves in tandem with that of fossil fuel consumption, but population growth has very lesser impact. The result showsthat other things remaining constant, a one percent increase in fossil fuel consumption, could cause an increase in the carbon dioxide emission by 0.97 %; and a one percent increase in population leads to an increase in the carbon dioxide emission by 0.07 %. The country-wise statistical analysis shows that the intercepts vary for all of the four countries, which may be due to the exogenous factors such as income, population, technology, political set-up, socio-economic factors etc. that are unique to each country. However, the larger difference of intercept is found in case of China. This may be due to use other sources of fuel that may be producing more CO_2 in China than in other countries. However, an analysis across time fails to show any variation in the carbon dioxide emission pattern. However, in case of variation in slope coefficients across the countries, only fossil fuel consumption variable is observed to be significantly varied across countries. Therefore, results of the study also indicate that the contribution to the growth of CO2 emission is strongly influenced by fossil fuel consumption growth of all four countries.

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